Introduction to webKORIGEN and Applications within NUCLEONICA

H.W. Wiese
Karlsruhe Institute of Technology

Introduction

- webKORIGEN is based on the Karlsruhe Isotope Generation and Depletion Code KORIGEN developed from the US-Code ORIGEN 2 (1400 nucl.)
- From the initial amount and composition of a nuclear fuel and a given irradiation history it determines the fuel nuclide inventory changed by neutron interactions and decays; initial actinides daughters and FP are calculated
- n-interactions: (n,f), (n,γ), (n,2n), (n,3n)
- Decays: α, β-, β+, internal transitions

Calculated Quantities for Nuclides and Chemical Elements

- Concentrations in Gramatoms (gat)
- Concentrations in Grams (g)
- Radioactivities in Becquerels (Bq)
- Total and γ-heat releases in Watts (W)
- Radiotoxicities for ingestion and inhalation (Sv)
- Gamma emission rates (γ/s)
- Neutron emission rates (n/s)

Nuclear Data

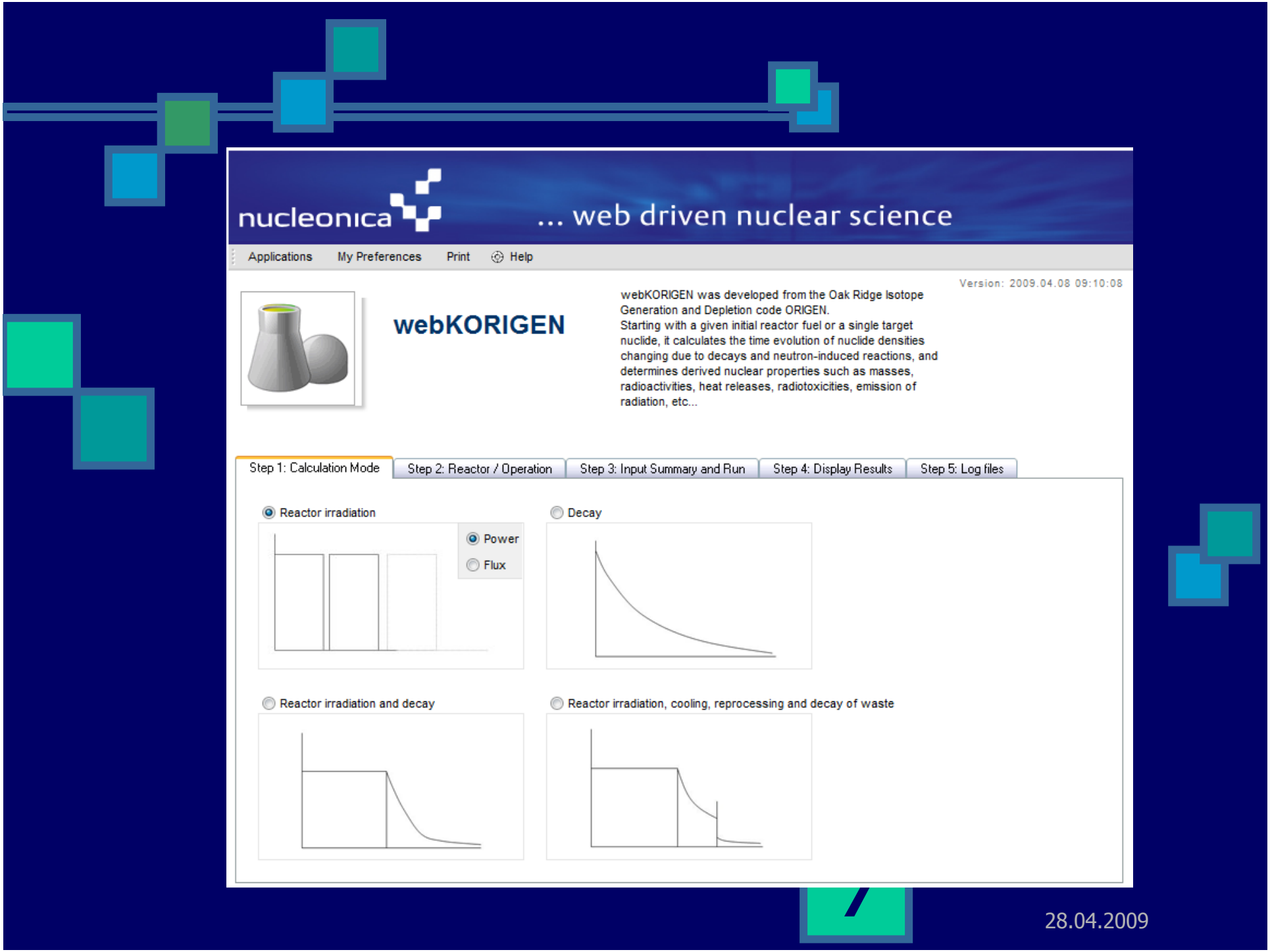
- Effective n-reaction cross sections have to be pre-calculated from σ(E) and the n-spectrum Φ(E) of the considered facility (subassembly) !
- webKORIGEN: PWR/BWR UOX/MOX libraries and 2200m/s x-sections for special applications, EFR MOX (European Fast Reactor) library
- Decay data, fission product yields, fission energy releases, dose conversion factors

webKORIGEN Guide Lines

- Follow-up nuclide generation in a neutron field (reactor, irradiation facility) and during subsequent decay of used fuel and waste
- **Allow easy input preparation restricted to simple basic applications**
- **Reduce output to top-20 quantities, e.g. Bq, at the end of irradiation/decay time interval**
- **Visualize results**

Operation in Modes with Results at End of Irradiation/Decay

- Mode 1: Power irradiation history given and time dependent neutron flux is derived, or a given neutron flux is used (target irrad.); k-infinity and masses are calculated
- Mode 2: Decay of a given nuclide
- Mode 3: Power irradiation as in Mode 1 but subsequent decay added; output provided for decay only
- Mode 4: As in Mode 3 but reprocessing and decay of waste is added; output provided for decay before and after reprocessing


nucleonica
... web driven nuclear science
Applications
My Preferences
Print
Help
Version: 2009.04.08 09:10:08
webKORIGEN
webKORIGEN was developed from the Oak Ridge Isotope Generation and Depletion code ORIGEN.
Starting with a given initial reactor fuel or a single target nuclide, it calculates the time evolution of nuclide densities changing due to decays and neutron-induced reactions, and determines derived nuclear properties such as masses, radioactivities, heat releases, radiotoxicities, emission of radiation, etc...
Step 1: Calculation Mode
Step 2: Reactor / Operation
Step 3: Input Summary and Run
Step 4: Display Results
Step 5: Log files
Reactor irradiation
Power
Flux
Decay
Reactor irradiation and decay
Reactor irradiation, cooling, reprocessing and decay of waste

Irradiation History

Power derived from Operation Parameters

- For maintaining criticality, power reactors are operated in cycles of ca. 1y length; discharge burnup of 50 – 60MWd/kgHM after 5 – 6 cycles
- During equilibrium operation at the end of each cycle fuel subassemblies with discharge burnup are unloaded and replaced by fresh S/U
- In webKORIGEN power irradiation is specified by burnup, cycle length, number of cycles and load factor

Single-Nuclide-Target Irradiation by Specification of

- Name and amount (Grams) of target nuclide
- Total neutron flux density Φ (n/cm**2/s)
- Neutron spectrum of the facility in which the irradiation is done (PWR/BWR UOX/MOX, fast reactor EFR or 2200m/s cross sections)
- A one-cycle constant-flux calculation is performed

Now the steps through webKORIGEN and results for selected applications will be presented

webKORIGEN

webKORIGEN was developed from the Oak Ridge Isotope Generation and Depletion code ORIGEN. Starting with a given initial reactor fuel or a single target nuclide, it calculates the time evolution of nuclide densities changing due to decays and neutron-induced reactions, and determines derived nuclear properties such as masses, radioactivities, heat releases, radiotoxicities, emission of radiation, etc...

Step 1: Calculation Mode | Step 2: Reactor / Operation | Step 3: Input Summary and Run | Step 4: Display Results | Step 5: Log files

Reactor type

- (•) PWR
- ( ) BWR
- ( ) EFR

Reactor Parameters

Burnup (MW_{th} · d / kg_{IHM}):

55

Total initial heavy metal mass (t_{IHM}):

20

Electrical efficiency (%):

34

Derived Power values

Specific Power: 37.65 MW / t_{IHM}

Thermal Power: 0.75 GW

Electrical Power: 0.26 GW

Update power values

Neutron Spectrum

- (•) UOX
  - U235/U (w/o): 4.0
- ( ) MOX

Nuclide	Weight (%)
Pu238/Pu (w/o)	2.6
Pu239/Pu (w/o)	50.5
Pu240/Pu (w/o)	27.8
Pu241/Pu (w/o)	11.5
Pu242/Pu (w/o)	7.6
Am241/Pu (w/o)	1.0

Uranium matrix

- (•) Natural
- ( ) Depleted

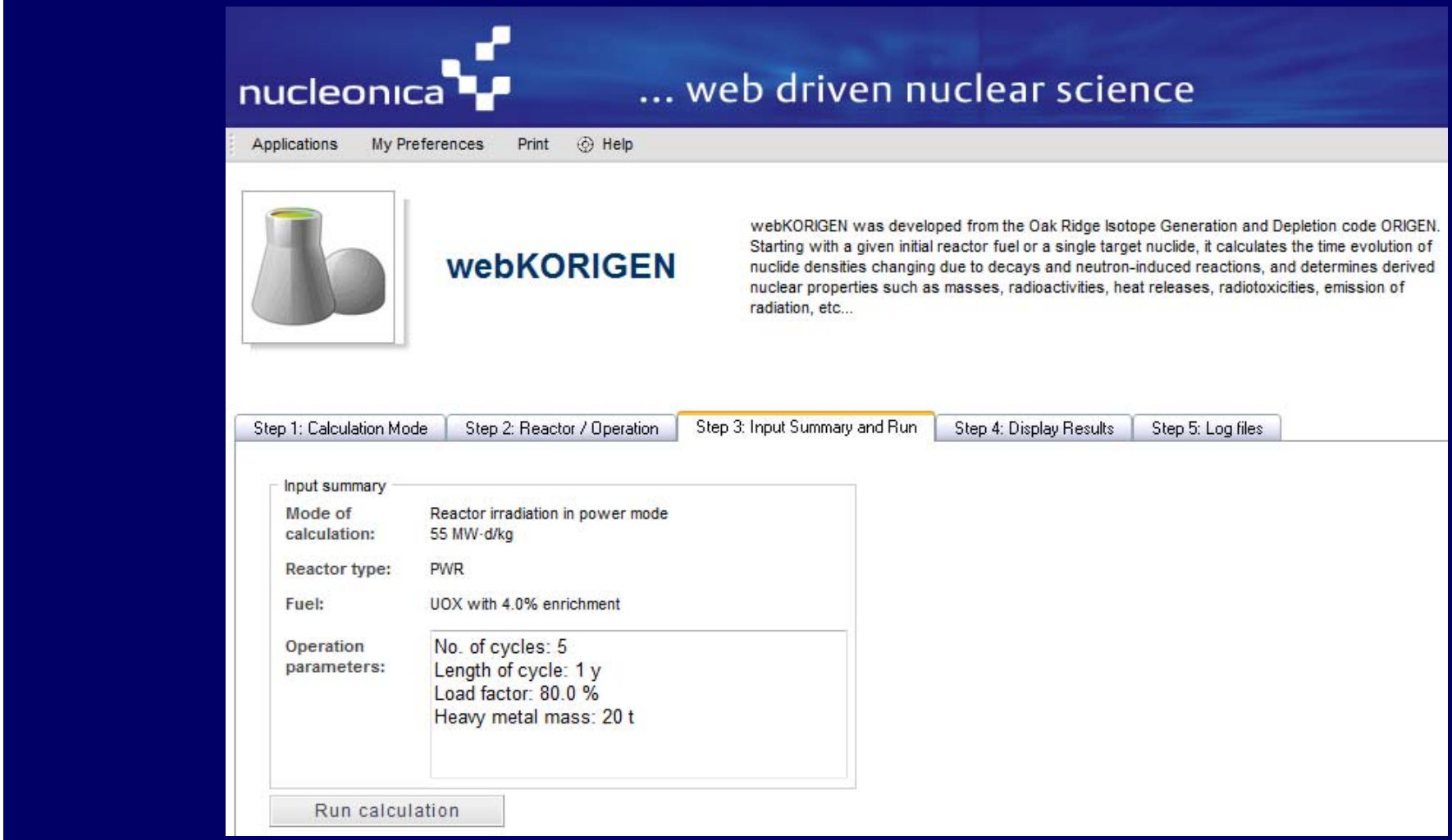
Pu_{fiss}/(U+Pu) (w/o): 3.8

Irradiation and decay parameters

No. of cycles	5	
Length of cycle	1	y
Load factor (%)	80.0	
Cooling time before reprocessing:	6	y
Decay time after reprocessing:	100000	y

Reprocessing ratio (%)

Uranium	99.9
Plutonium	99.9
Neptunium	99.5
Americium	99.5
Curium	99.5


nucleonica
... web driven nuclear science
Applications
My Preferences
Print
Help
webKORIGEN
webKORIGEN was developed from the Oak Ridge Isotope Generation and Depletion code ORIGEN. Starting with a given initial reactor fuel or a single target nuclide, it calculates the time evolution of nuclide densities changing due to decays and neutron-induced reactions, and determines derived nuclear properties such as masses, radioactivities, heat releases, radiotoxicities, emission of radiation, etc...
Step 1: Calculation Mode
Step 2: Reactor / Operation
Step 3: Input Summary and Run
Step 4: Display Results
Step 5: Log files
Input summary
Mode of calculation:
Reactor irradiation in power mode
55 MW-d/kg
Reactor type:
PWR
Fuel:
UOX with 4.0% enrichment
Operation parameters:
No. of cycles: 5
Length of cycle: 1 y
Load factor: 80.0 %
Heavy metal mass: 20 t
Run calculation

webKORIGEN

webKORIGEN was developed from the Oak Ridge Isotope Generation and Depletion code ORIGEN. Starting with a given initial reactor fuel or a single target nuclide, it calculates the time evolution of nuclide densities changing due to decays and neutron-induced reactions, and determines derived nuclear properties such as masses, radioactivities, heat releases, radiotoxicities, emission of radiation, etc...

Step 1: Calculation Mode | Step 2: Reactor / Operation | Step 3: Input Summary and Run | Step 4: Display Results | Step 5: Log files

Display results for nuclides/elements dominant at 4.8 y irradiation

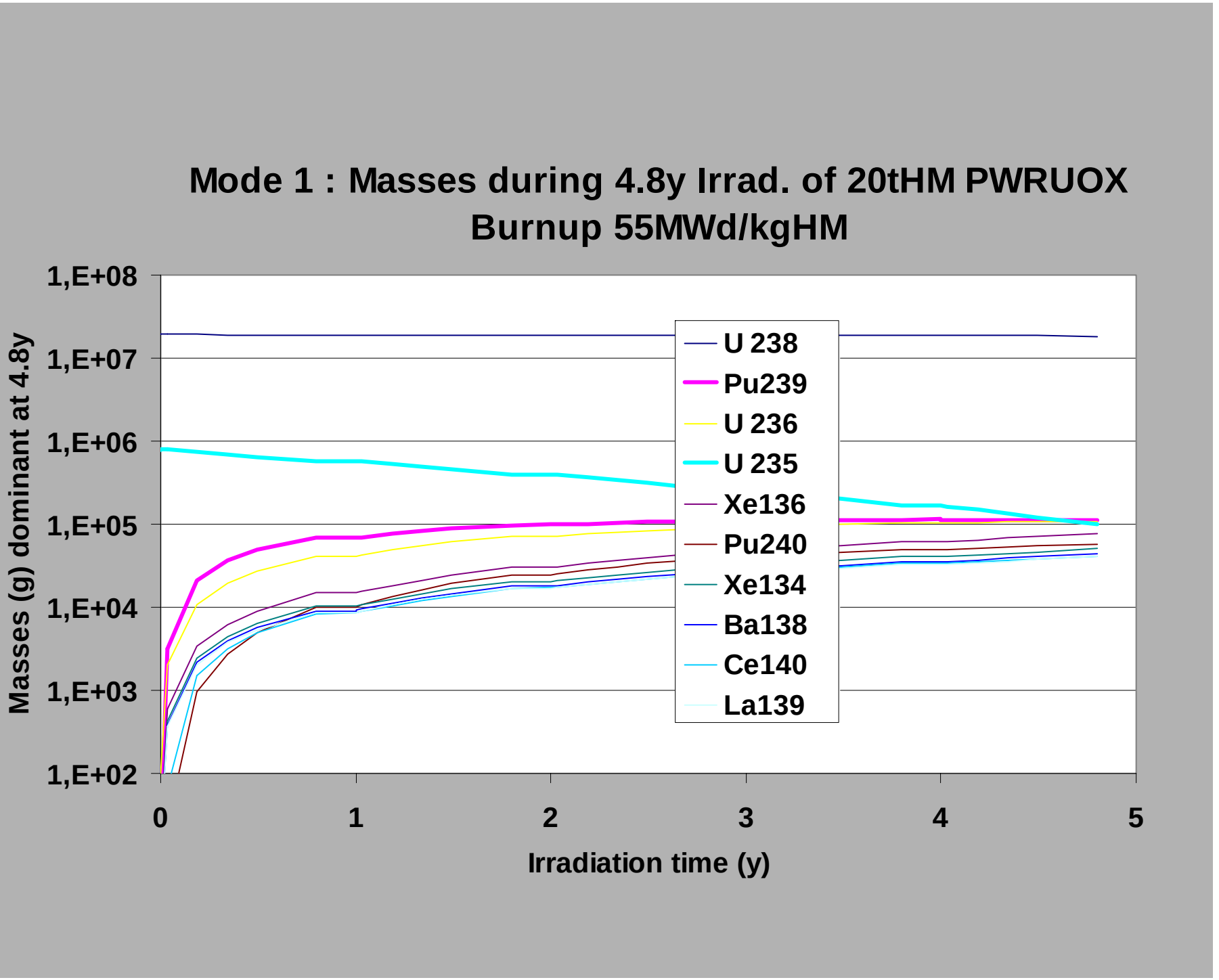
Display quantity: Mass (g)

Top Nuclides	Results
U238	1.840e+7
Pu239	1.108e+5
U236	1.090e+5
U235	9.926e+4
Xe136	7.742e+4
Pu240	5.826e+4
Xe134	5.047e+4
Ba138	4.382e+4
Ce140	4.190e+4
La139	4.027e+4
Cs137	4.018e+4
Nd144	3.984e+4
Ce142	3.782e+4
Xe132	3.627e+4
Pr141	3.621e+4
Cs133	3.475e+4
Pu241	3.472e+4
Mo100	3.002e+4
Mo98	2.864e+4
Zr96	2.664e+4

Top Elements	Results
Uranium	1.861e+7
Plutonium	2.331e+5
Xenon	1.743e+5
Neodymium	1.214e+5
Zirconium	1.169e+5
Molybdenum	1.092e+5
Cesium	9.235e+4
Cerium	8.796e+4
Barium	5.028e+4
Lanthanum	4.035e+4
Praseodymium	3.665e+4
Krypton	1.157e+4

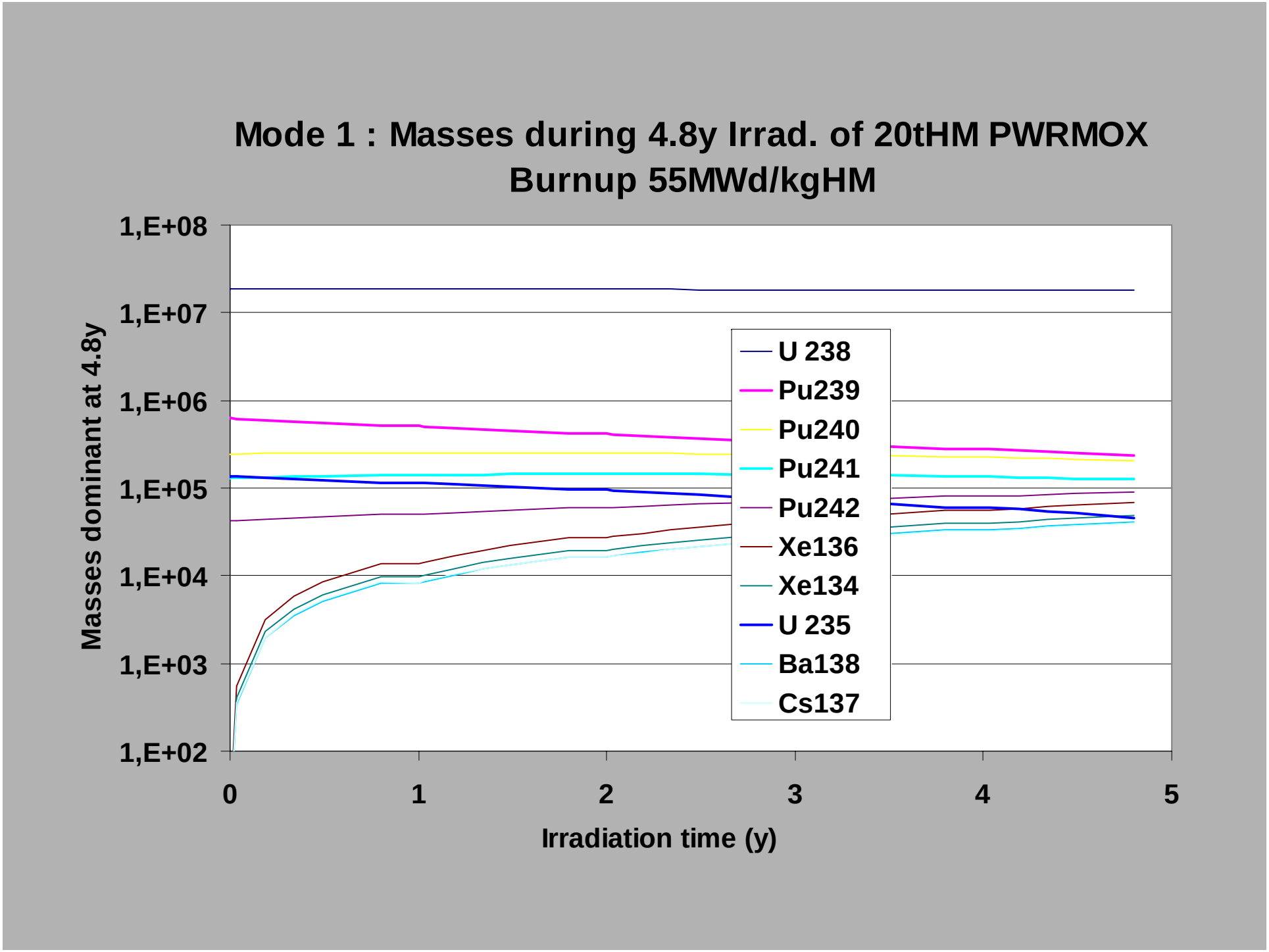
Totals	Results
Actinides:	1.887e+7
Fission Products:	1.126e+6
Total:	2.000e+7

Plot K∞ | Plot Nuclides | Plot Elements | Plot Total


Mode 1 : Masses during 4.8y Irrad. of 20tHM PWRUOX
Burnup 55MWd/kgHM
Masses (g) dominant at 4.8y
1,E+08
1,E+07
1,E+06
1,E+05
1,E+04
1,E+03
1,E+02
0
1
2
3
4
5
Irradiation time (y)
U 238
Pu239
U 236
U 235
Xe136
Pu240
Xe134
Ba138
Ce140
La139

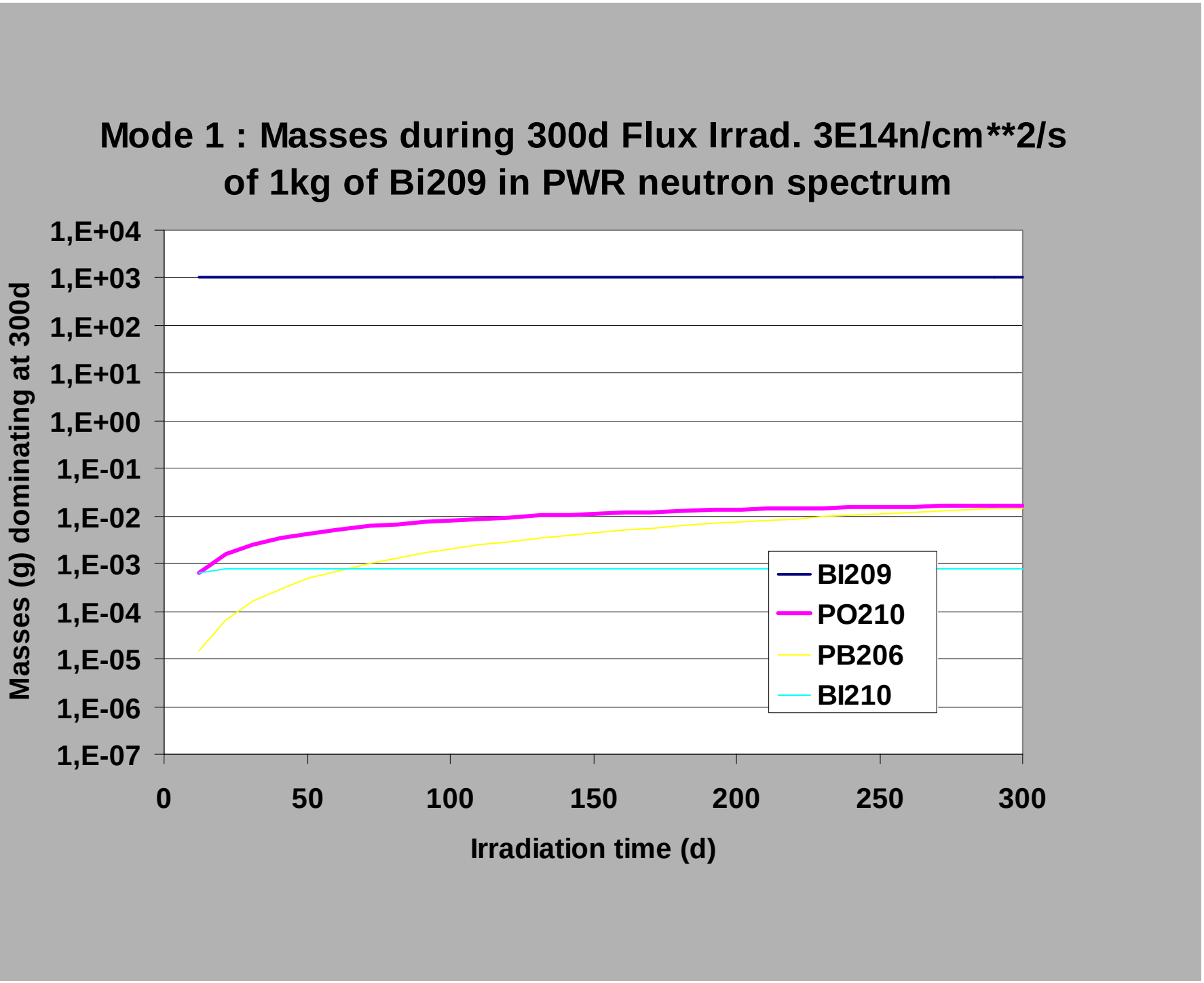
Comments

- In UOX fuel there is no Pu at irradiation start-up
- During shut-down for reloading long-lived nuclides masses stay constant
- Fissile U235 is depleted, fissile Pu239 is generated, at end of irradiation here Pu239 = U235
- Power generation is succesively taken over by fission of Pu239
- Fission products are generated


Mode 1 : Masses during 4.8y Irrad. of 20tHM PWRMOX
Burnup 55MWd/kgHM
Masses dominant at 4.8y
1,E+08
1,E+07
1,E+06
1,E+05
1,E+04
1,E+03
1,E+02
0
1
2
3
4
5
Irradiation time (y)
U 238
Pu239
Pu240
Pu241
Pu242
Xe136
Xe134
U 235
Ba138
Cs137

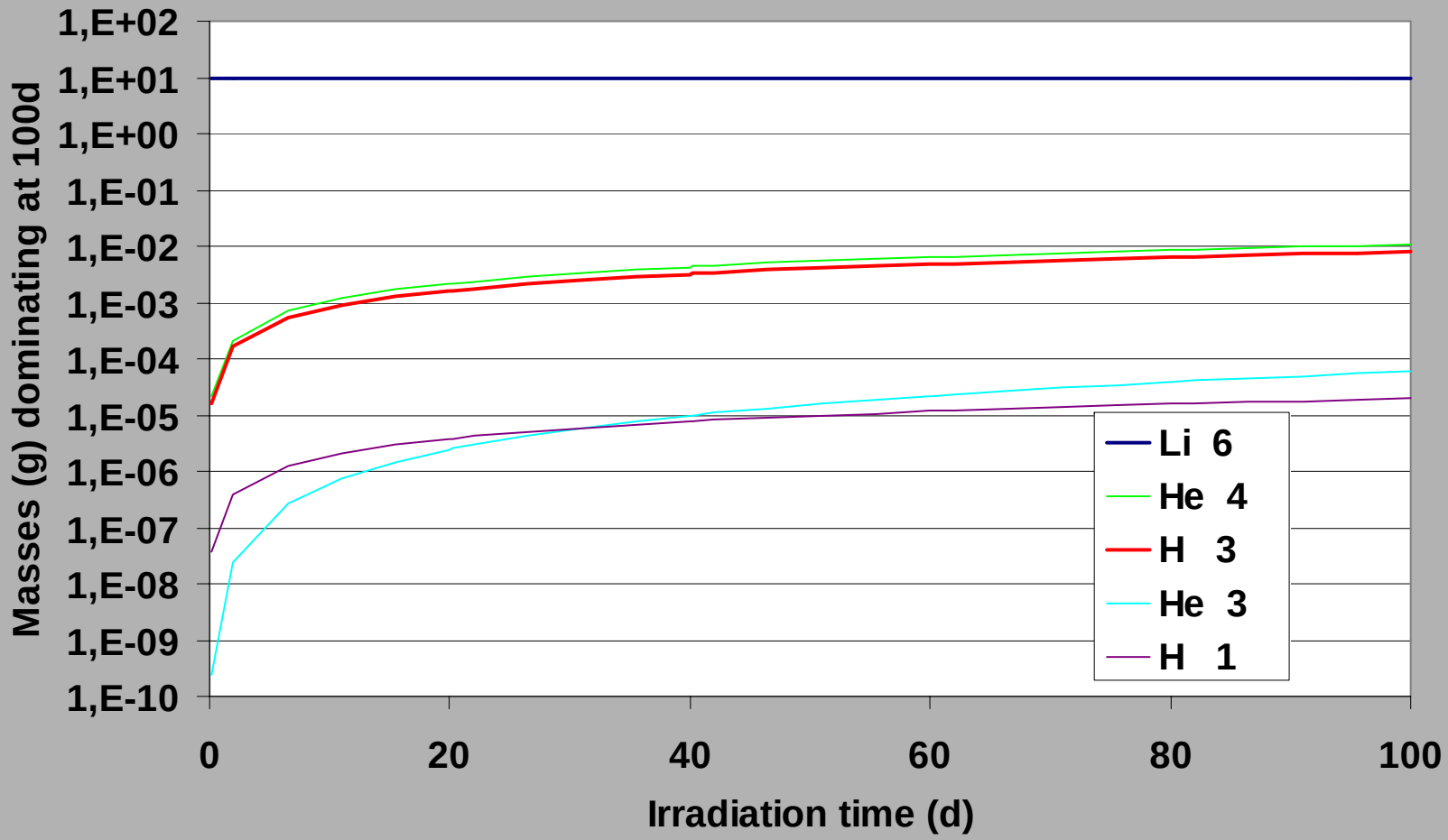
Comments

- The fresh MOX fuel is made-up of 3.8% fissile Pu in heavy material and U-nat
- Fissile Pu239, Pu241 and U235 are depleted


Mode 1 : Masses during 300d Flux Irrad. 3E14n/cm**2/s
of 1kg of Bi209 in PWR neutron spectrum
Masses (g) dominating at 300d
1,E+04
1,E+03
1,E+02
1,E+01
1,E+00
1,E-01
1,E-02
1,E-03
1,E-04
1,E-05
1,E-06
1,E-07
0
50
100
150
200
250
300
Irradiation time (d)
BI209
PO210
PB206
BI210

Comments

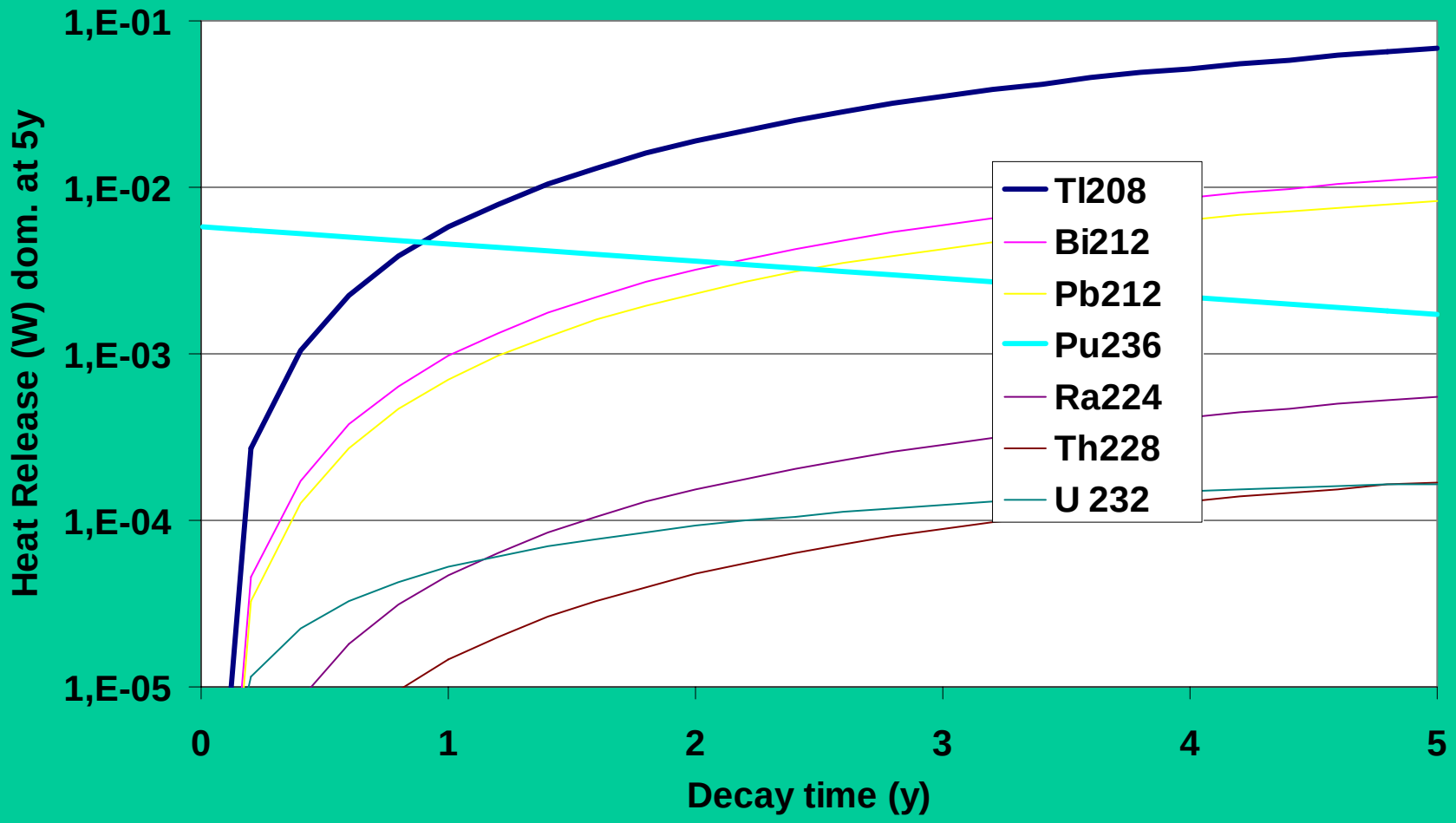
- The formation of strongly radiotoxic Po210 from Bi209 was one of Joe Magill's favourites
- 100 days irradiation of 1kg Bi209 in a PWR produces 10mg Po210
- See also E. Krögers contribution this Training Course


Mode 1 : Masses during 100d Irrad. of 10g Li6
3E15n/cm**2/s Fast-Neutron Spectrum
Masses (g) dominating at 100d
1,E+02
1,E+01
1,E+00
1,E-01
1,E-02
1,E-03
1,E-04
1,E-05
1,E-06
1,E-07
1,E-08
1,E-09
1,E-10
0
20
40
60
80
100
Irradiation time (d)
Li 6
He 4
H 3
He 3
H 1

Comments

- Tritium breeding from Li6 in a fusion reactor blanket
- Fast fission reactor cross sections were used to get a rough estimate
- Fusion reactor blanket cross sections are not available within webKORIGEN

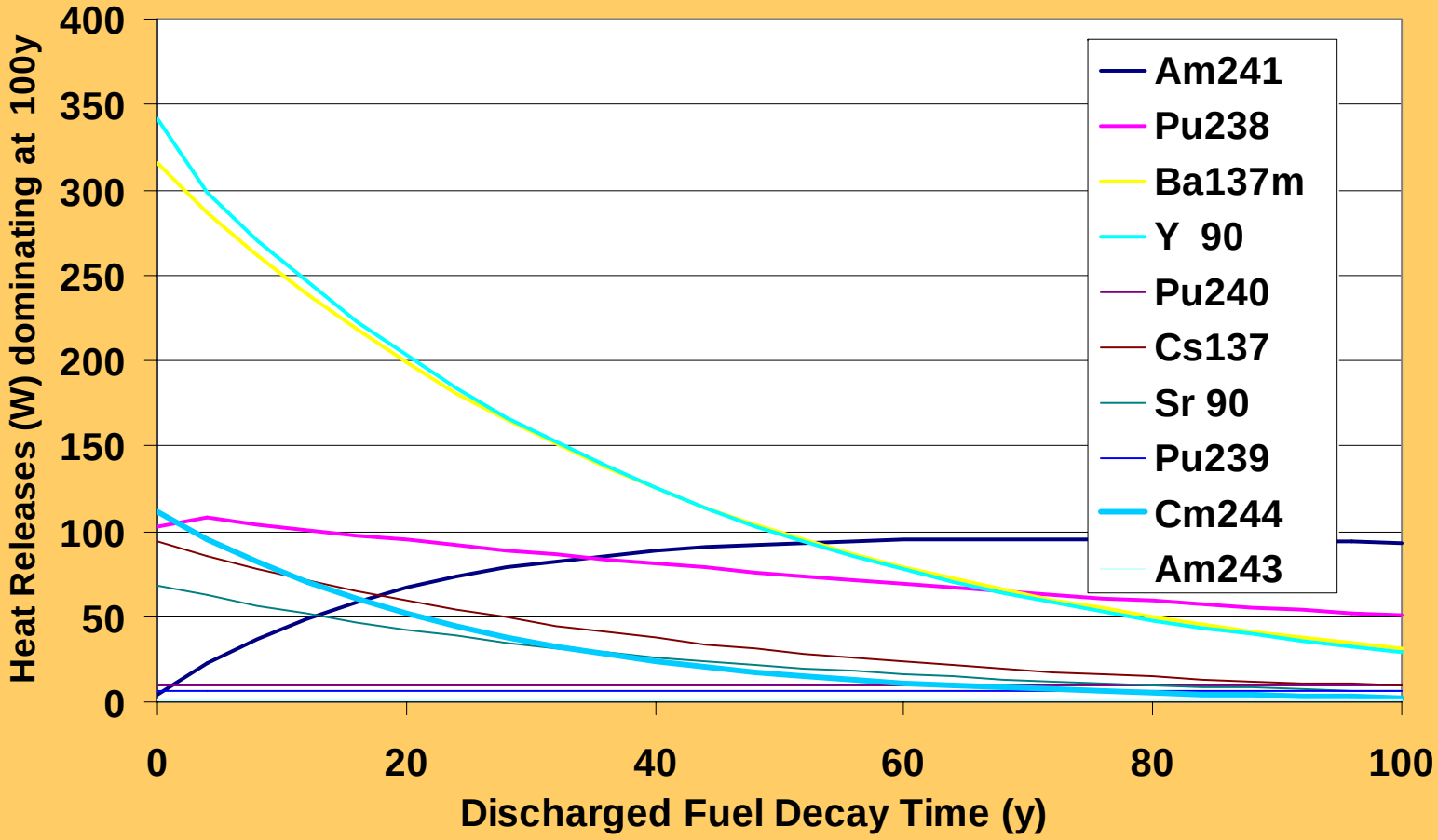
Mode 2 : Gamma Heat Release during 5y Decay of 1g Pu236



Comment

- Production of Tl208 is investigated for deterioration of fuel

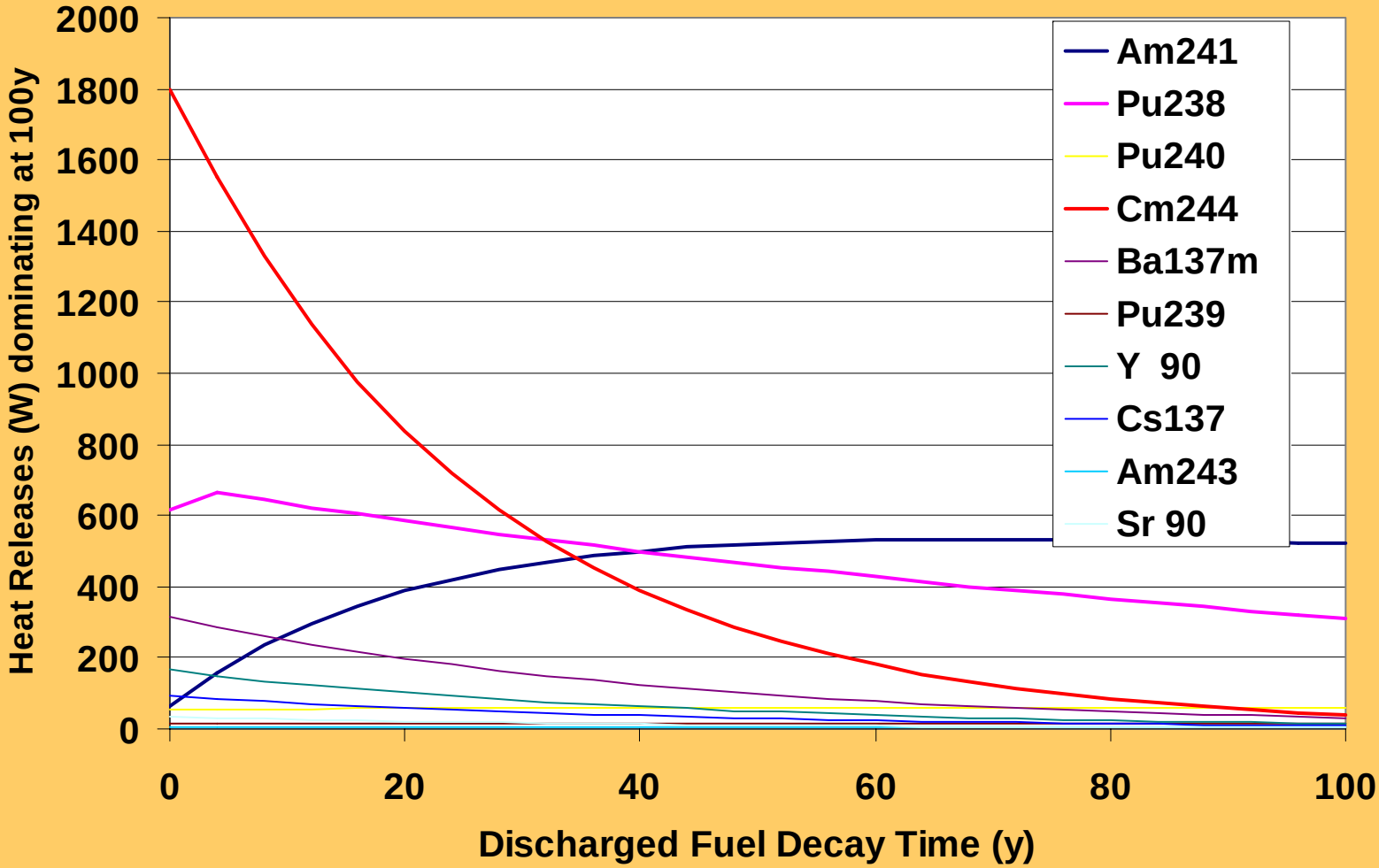
Mode 3 : Total Heat during Decay of 535kgHM PWRUOX Burnup 50MWd/kgHM



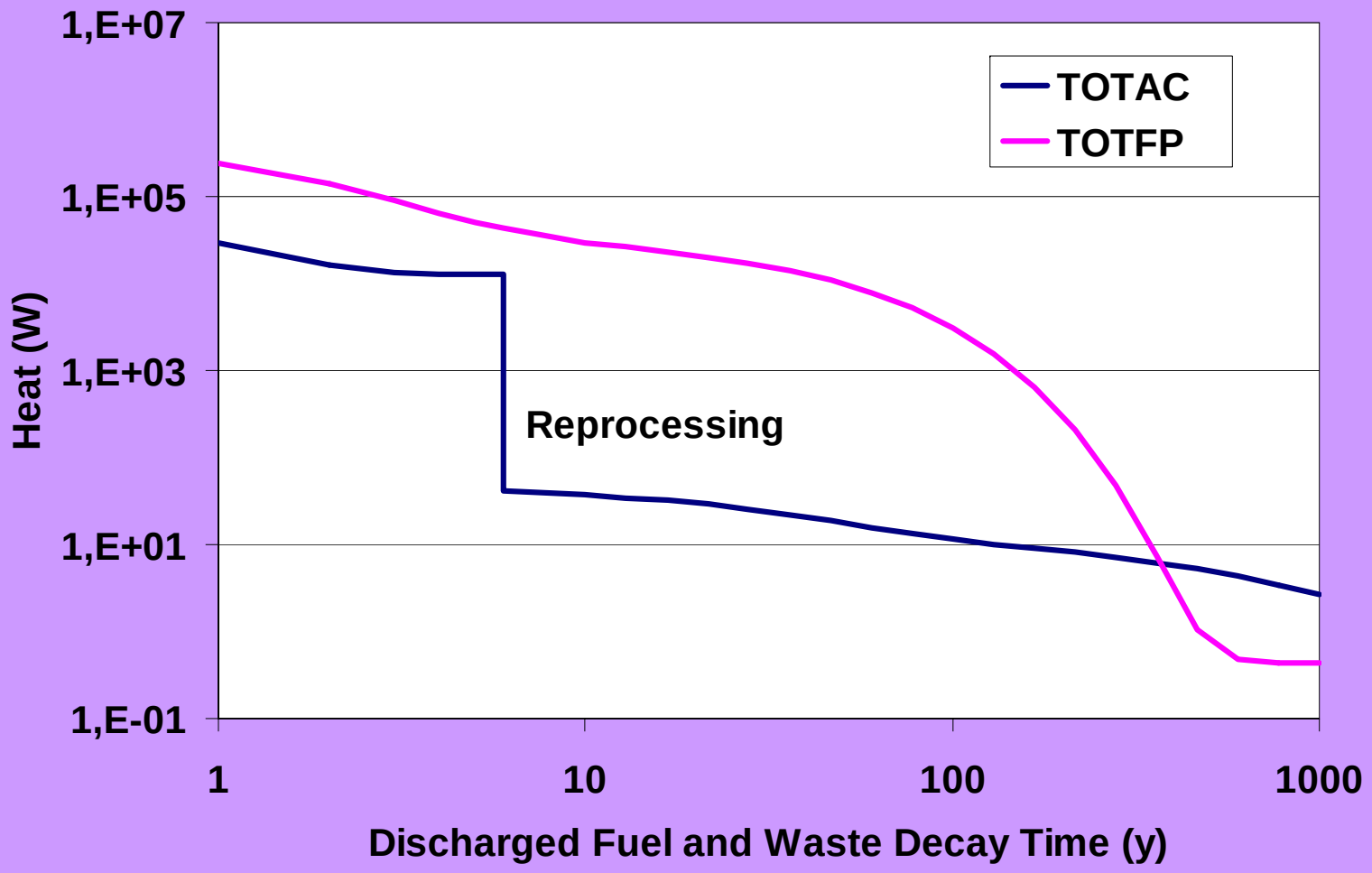
Comments

- This and the following flow sheet contain results to be compared with those from the new German Decay Heat Standard (DIN)
- Reference PWR UOX and MOX fuel subassemblies (535kgHM) are considered
- In MOX fuels heat production of transuranium isotopes, especially Cm244, plays an important role

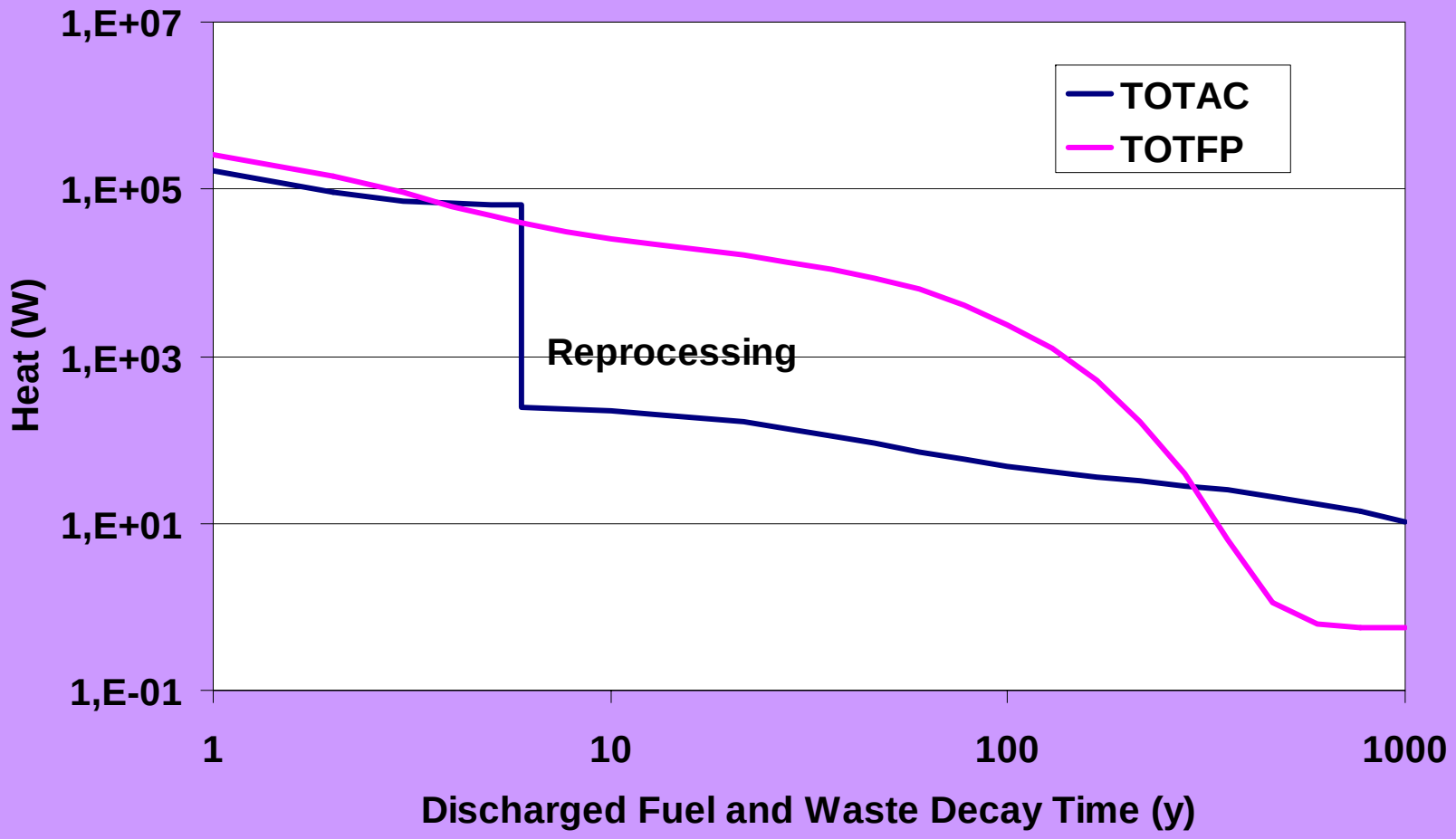
Mode 3 : Total Heat during 100y decay of 535kgHM PWRMOX Burnup 50MWd/kgHM



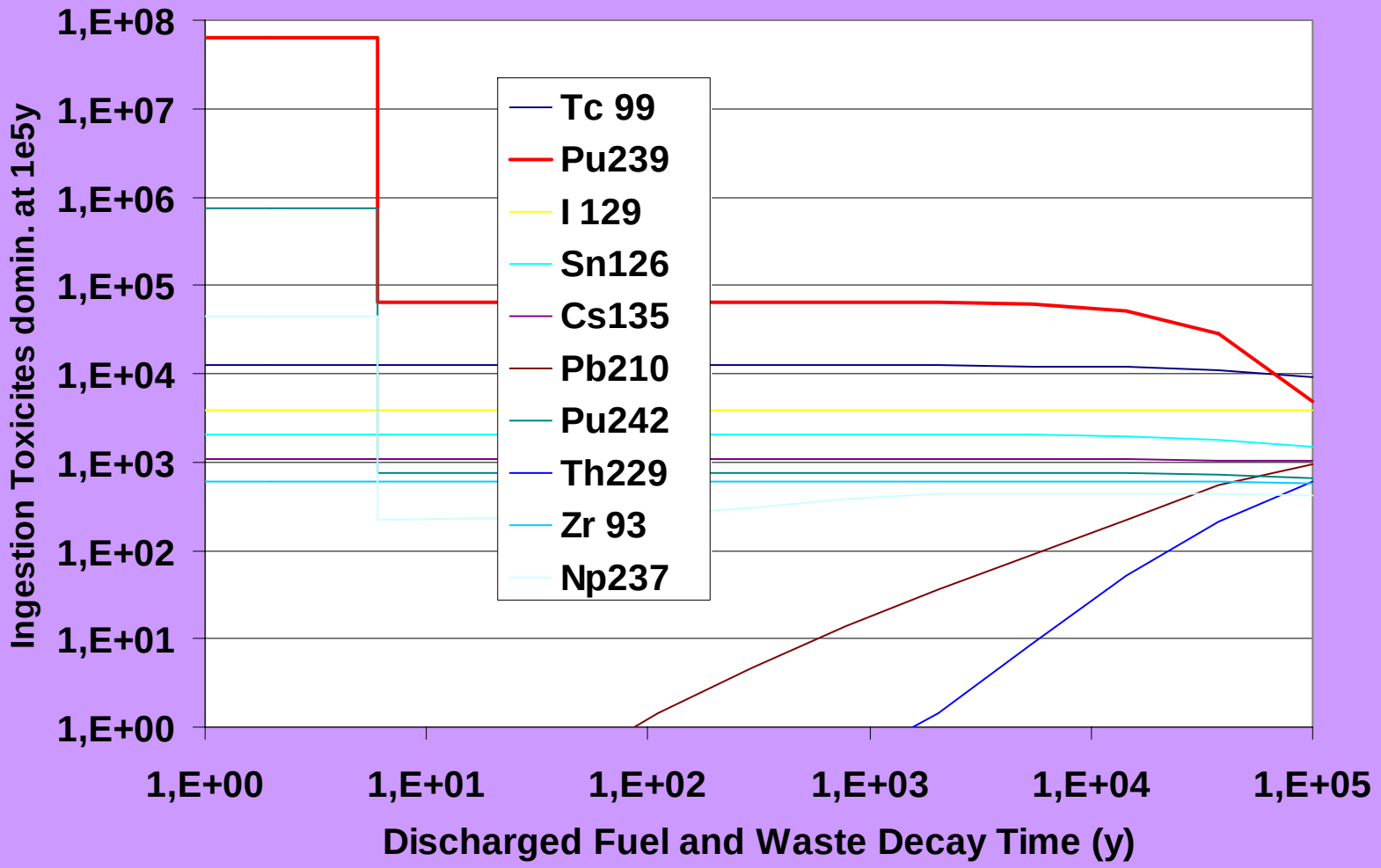
Mode 4 : Heat Release during 1000y Decay 20tHM
PWRUOX Burnup 55MWd/kgHM

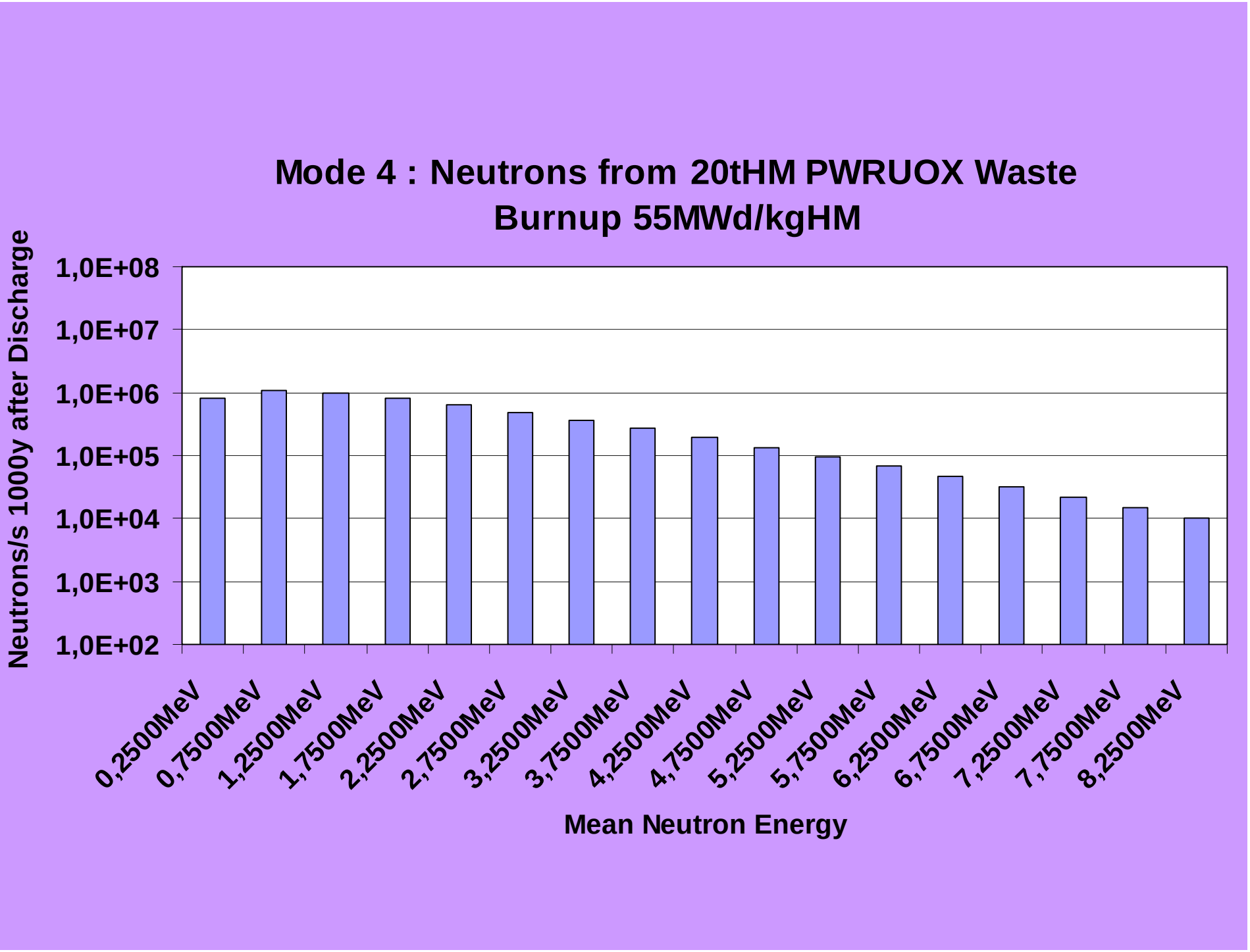


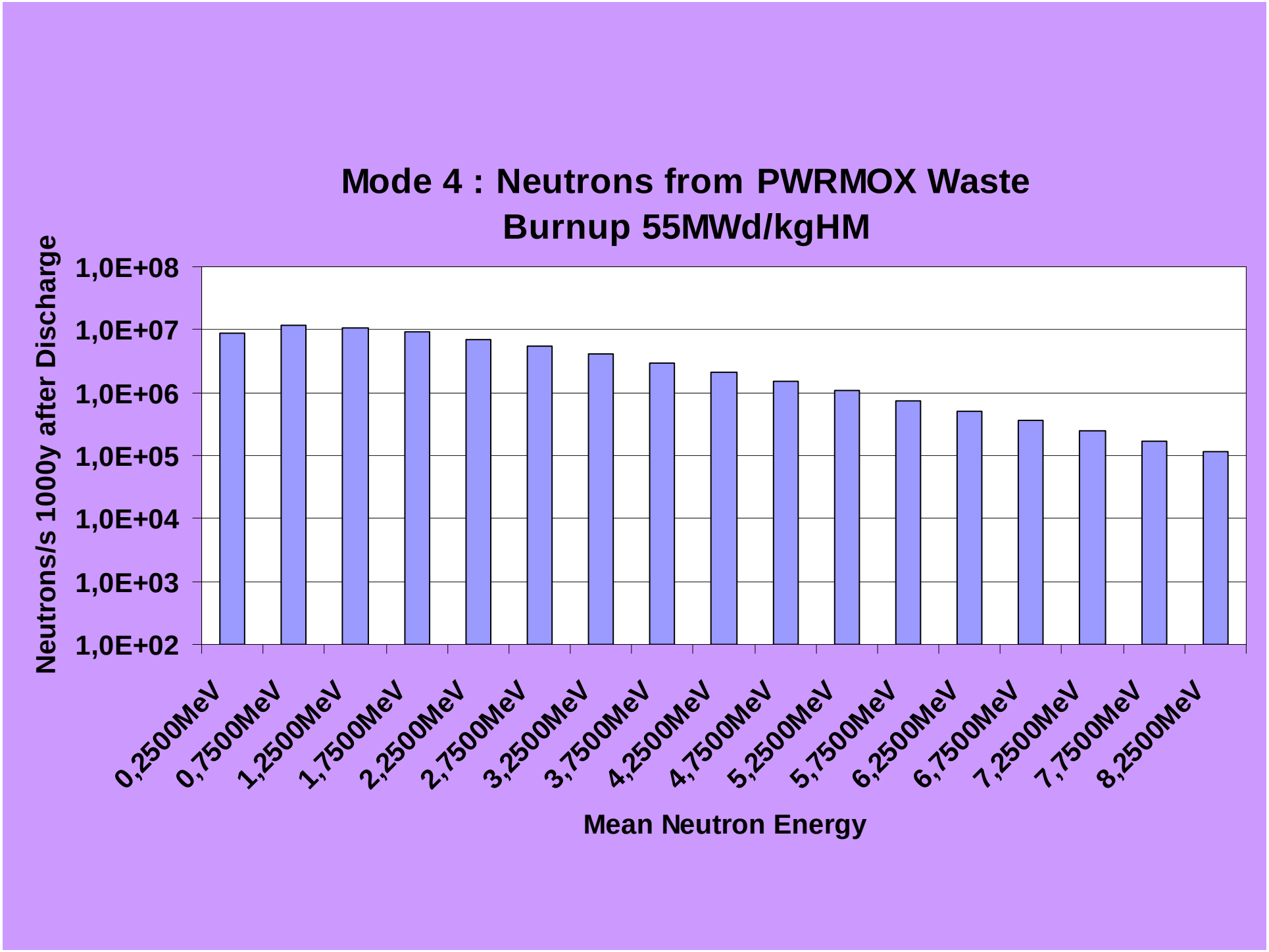
Mode 4 : Heat Release during 1000y Decay 20tHM
PWRMOX Burnup 55MWd/kgHM

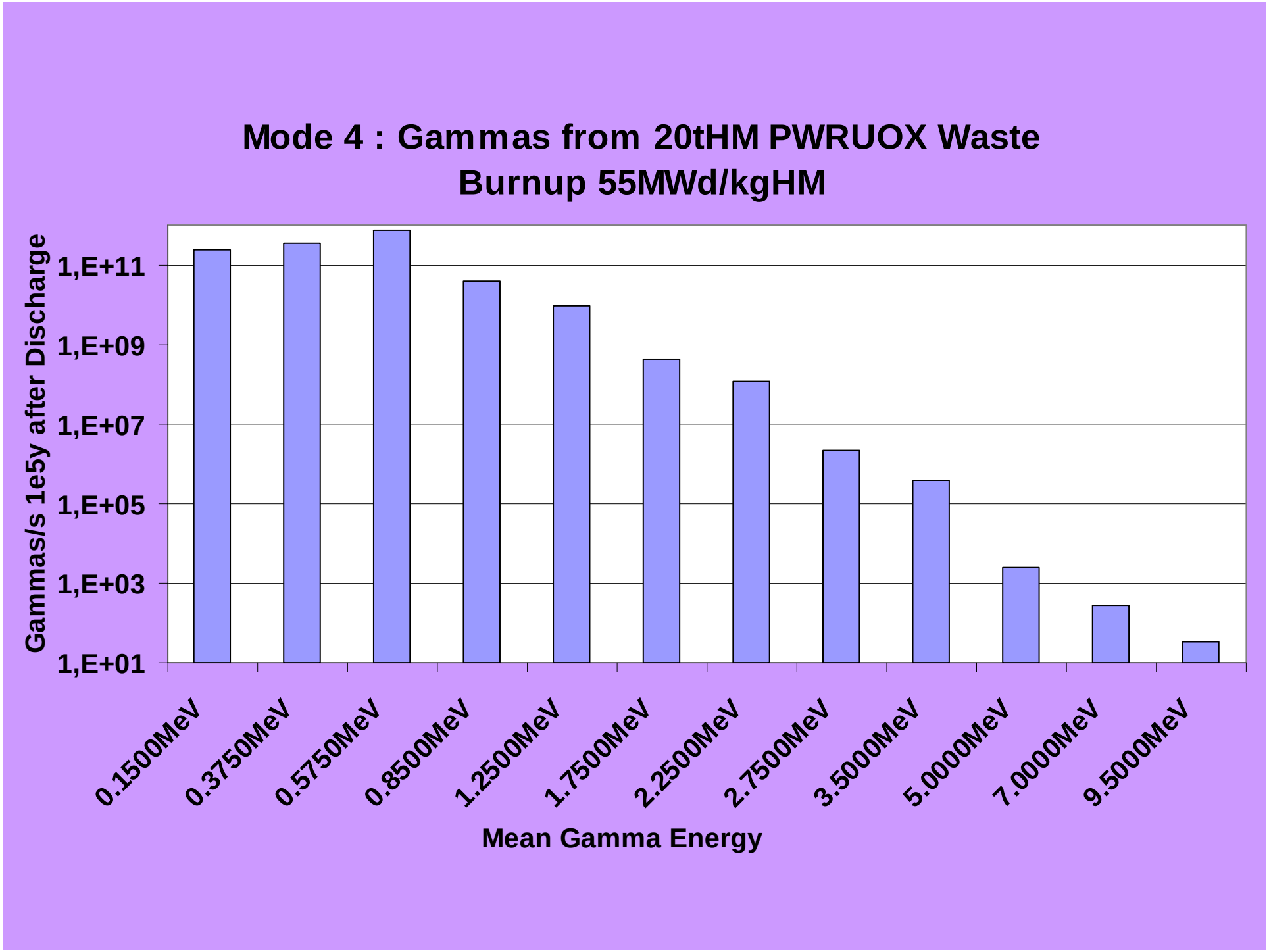


Mode 4 : Ingestion Toxicity during Decay of 20tHM PWRUOX Burnup 55MWd/kgHM




Mode 4 : Neutrons from 20tHM PWRUOX Waste
Burnup 55MWd/kgHM
Neutrons/s 1000y after Discharge
1,0E+08
1,0E+07
1,0E+06
1,0E+05
1,0E+04
1,0E+03
1,0E+02
0,2500MeV
0,7500MeV
1,2500MeV
1,7500MeV
2,2500MeV
2,7500MeV
3,2500MeV
3,7500MeV
4,2500MeV
4,7500MeV
5,2500MeV
5,7500MeV
6,2500MeV
6,7500MeV
7,2500MeV
7,7500MeV
8,2500MeV
Mean Neutron Energy


Mode 4 : Neutrons from PWRMOX Waste
Burnup 55MWd/kgHM
Neutrons/s 1000y after Discharge
1,0E+08
1,0E+07
1,0E+06
1,0E+05
1,0E+04
1,0E+03
1,0E+02
0,2500MeV
0,7500MeV
1,2500MeV
1,7500MeV
2,2500MeV
2,7500MeV
3,2500MeV
3,7500MeV
4,2500MeV
4,7500MeV
5,2500MeV
5,7500MeV
6,2500MeV
6,7500MeV
7,2500MeV
7,7500MeV
8,2500MeV
Mean Neutron Energy


Mode 4 : Gammas from 20tHM PWRUOX Waste
Burnup 55MWd/kgHM
Gammas/s 1e5y after Discharge
1,E+11
1,E+09
1,E+07
1,E+05
1,E+03
1,E+01
0.1500MeV
0.3750MeV
0.5750MeV
0.8500MeV
1.2500MeV
1.7500MeV
2.2500MeV
2.7500MeV
3.5000MeV
5.0000MeV
7.0000MeV
9.5000MeV
Mean Gamma Energy

nucleonica [wiki]

navigation
- Main Page
- Community portal
- Current events
- Recent changes
- Random page
- Help
- Glossary

search
Go Search

toolbox
- What links here
- Related changes
- Upload file
- Special pages
- Printable version
- Permanent link

help | discussion | edit | history | delete | move | watch

Help:WebKORIGEN

webKORIGEN: A New web-based KORIGEN Package for Nuclide Depletion Calculations in Nucleonica

H.W. Wiese, A. Schwenk-Ferrero

Forschungszentrum Karlsruhe Technik und Umwelt, Postfach 3640, 76021 Karlsruhe, Germany

mailto: Aleksandra.Schwenk-Ferrero@iket.fzk.de

Contents [hide]

The KORIGEN code and its nuclear data libraries [edit]

Origin and utilization [edit]

The KORIGEN code, developed in the Karlsruhe Research Centre, is a stand alone-package which serves to calculate the fuel depletion during irradiation(burn-up) and decay [1]. KORIGEN, originating from the ORNL ORIGEN code [2] can be used to determine some characteristics of spent

Summary

- webKORIGEN allows to follow up the changes of a nuclear reactor material or a single-nuclide target due to neutron interactions and decays; a diversity fuel properties is provided for top-20 nuclides at irradiation/decay end
- Restriction : Irradiation neutron spectra are limited to typical PWR/BWR UOX/MOX or an EFR type (European Fast Reactor) fuel